Docket No. 2001-067-TAP

BARCODE SINGLE LASER SCANNER TARGETING

BACKGROUND OF THE INVENTION

1. Field of the Invention:

The present invention relates generally to an apparatus for calibrating an apparatus for retrieving objects from an array of storage cells.

2. Background of the Invention:

Storage library systems are capable of storing and rapidly retrieving large quantities of information stored on storage media cartridges. Such storage library systems often use robotic mechanisms to improve the speed of information retrieval and the reliability of maintaining the storage library cartridge inventory. These robotic mechanisms typically comprise a hand mechanism positioned on a movable arm. To retrieve information, the robotic arm is moved to position the hand near the inventory location of a desired media cartridge. The hand is then activated to grip the desired cartridge and remove it from the library inventory location. The robotic arm with the hand gripping the cartridge then moves to an appropriate position to further process the cartridge. In this manner, the robotic hand manipulates the cartridge for access to information stored on the cartridge.

However, in order to grip the cartridge, the position of the robotic arm with respect to the cartridge

within the library must be determined. Positional accuracy of the robotic arm and any devices attached thereto affects both the repeatability of an operation as well as the ability of the robotic arm to accurately perform the particular task required of it. There are many different arm calibration arrangements known in the art, and many of these entail the use of some sort of sensor to determine the position of the robotic arm.

A common method of calibrating the position of the robotic arm gripper mechanism is to use a vision system to orient the robotic arm with respect to one or more baseline targets located in the work space. Often these vision systems are located underneath or above the robotic arm and are oriented at an angle relative to the robotic arm. These vision systems are located at an angle so that a target on the work space can be imaged, and then a target located on a part of the robotic arm that is extended into the field of view of the vision system is imaged. The two images are compared and the position of the robotic arm is adjusted such that the target on the robotic arm is aligned with the target on the work piece when extended.

However, orienting the vision system at an angle causes the inclusion of the vision system with the robotic arm to take up a large amount of space. Thus, a significant portion of the space within the storage library system is unusable for placing storage cells. This is due to the fact that if, for example, the vision system is located below the robotic arm, an amount of space equal to the height or thickness of the angled

vision system at the bottom of the storage retrieval system cannot be accessed by the robotic arm since the vision system comes into contact with the floor of the storage library system before the robotic arm. Thus, the robotic arm is prevented from going low enough within the storage library system to engage and retrieve an object stored in a storage cell located within the thickness of the angled vision system from the floor of the storage library system.

However, as the need to store more and more data increases and the price paid for space also increases, the amount of money necessary to store data is increased. Thus, the wasted space within a library storage system becomes more and more intolerable. Therefore, there is a need for a calibration system that requires less space than current systems and that allows for a denser concentration of storage cells within a storage library system.

SUMMARY OF THE INVENTION

The present invention provides a robot apparatus and a barcode scanner to be used for collecting positional data parallel to the scan direction in, for example, a library storage system. In one embodiment, the robotic apparatus includes a barcode scanner with a scan path and an attenuation surface within the scanner scan path. The barcode scanner scans the target while the robotic apparatus is moved in a direction parallel with the scan path. Positional data is collected in conjunction with the readability limits of the barcode target. The central position of the target in a parallel direction to the scan path is determined based on the readability of the barcode target and the correlating positional data. The barcode scanner can also scan the target while the robotic apparatus is moved in a direction perpendicular with the scan path. Positional data is collected in conjunction with the readability limits of the barcode target. The central position of the target in a perpendicular direction to the scan path is determined based on the readability of the barcode scanner and the correlating positional data.

BRIEF DESCRIPTION OF THE DRAWINGS

The novel features believed characteristic of the invention are set forth in the appended claims. The invention itself, however, as well as a preferred mode of use, further objectives and advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in conjunction with the accompanying drawings, wherein:

Figure 1 depicts a top view of the overall architecture of a typical automated robotic tape library system wherein the calibration system of the present invention is employed;

Figure 2 depicts a side view of a segment of library system in accordance with the present invention;

Figure 3 shows a perspective cutaway view of a tape library system showing several of the plurality of locations of target;

Figure 4 illustrates the environment shown in **Figure 3** wherein the robotic arm retrieval mechanisms shown in **Figure 3** is grasping a tape cartridge with the robotic arm target positioned in close proximity to a cartridge cell;

Figure 5 depicts a diagram illustrating a calibration target in accordance with the prior art;

Figure 6 depicts a top view diagram of a barcode scan apparatus suitable for use with a cartridge retrieval system in accordance with the present invention;

Figure 7 depicts a side view diagram illustrating a method of determining the Z target position center in accordance with the present invention;

Figure 8 depicts a barcode target that may be used in conjunction with the barcode laser scanner of the present invention; and

Figure 9 depicts a top view diagram depicting more detail about the aperture associated with the barcode scan apparatus in accordance with the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

With reference now to the Figures and, in particular, with reference to **Figure 1**, a top view of the overall architecture of a typical automated robotic tape library system **100** wherein the calibration system of the present invention is employed is depicted. A typical automated library system operates to store and retrieve a large number of magnetic tape cartridges for an associated host processor. Library system **100** includes an array **120** of circularly arranged cells **130** for storing magnetic tape cartridges. A robotic arm **110** is pivotally rotatable about the center of array **120** and contains a tape cartridge retrieval mechanism **145**.

Referring now to **Figure 2**, a side view of a segment of library system **100** is depicted in accordance with the present invention. Tape cartridge retrieval mechanism **145** is located in a position for retrieving and replacing tape cartridges in the tape cartridge storage cells **130**. The retrieved tape cartridges are loaded into a tape transport mechanism (tape drives) **210** in response to a read/write request from a host computer (not shown) which is connected to library system **100**. Tape cartridge storage cells **130** and tape drives **210** are arranged in columns **125** which are grouped in "panels" **135**.

Library system **100** is provided as an example of a library system in which the present invention may be implemented. However, the present invention is not limited to use in silo type library systems, but may be

used in any other type of library system, such as, for example, linear library systems and U-shaped library systems.

Referring now to **Figures 3** and **4**, perspective cutaway views of a prior art robotic arm and storage cells suitable for use with tape library system **100** are depicted. **Figure 3** shows a perspective cutaway view of a tape library system showing several of the plurality of locations of target **300**.

In the prior art, one or more "N"-shaped calibration targets **300** are located on each column **125** of tape cartridge storage cells **130**. The position of the robotic arm **110** with respect to the tape cartridge storage cells **130** is determined and adjusted by using a line scan camera vision system **360** to scan these calibration targets **300** located in each of the columns **125**. An "N"-shaped target **300'** located on the cartridge retrieval mechanism **145** is also used to calibrate the position of the camera **360** with respect to the cartridge retrieval mechanisms **145**.

Figure 4 illustrates the environment shown in **Figure 3** wherein the robotic arm retrieval mechanisms shown in **Figure 3** is grasping a tape cartridge **340** with the robotic arm target **300** positioned in close proximity to a cartridge cell.

Referring now to **Figure 5**, a diagram illustrating a calibration target, which can be implemented as calibration target **300** in **Figure 3**, is depicted in accordance with the prior art. Position calibration target **300** comprises two elements, a background **504** and a

plurality of positioning indicia **501-503** imprinted thereon. The positioning indicia **501-503** and the background **304** are selected to be easily distinguishable from each other to enable the line scan camera system to precisely delimit the plurality of positioning indicia **501-503** from the background **504.** This is accomplished by the use of contrasting colors whose reflectivity is significantly different. An example of this would be the use of white positioning indicia **501-503** printed on a black background **504.** The use of this difference in reflectivity simplifies the task of the line scan camera to delimit the position and boundaries of the plurality of positioning indicia **501-503.** Alternatively, other methods that provide high contrast, such as, for example, light producing elements, may be used to produce the target.

As illustrated in **Figure 5**, the plurality of positioning indicia **501-503** comprise a pair of parallel oriented, spaced apart, substantially rectangular bars **501** and **502**, each of which has a first end and a second end with, for example, the first end being located at the top of **Figure 5** and the bottom end being located at the bottom of **Figure 5** for the purpose of this description. The third positioning indicia comprises diagonal bar **503** which is substantially parallelogram shaped and extends diagonally from the first end of indicia **501** to the second end of indicia **502** such that indicia **503** comprises a diagonal bar that can be used as described below to assist in the position determination process. Each of the parallel indicia **501, 502** is of substantially the

same dimensions having a width **W1** and a height **H1** while the parallelogram shaped bar **503** has a width **W2** and a height **H1**. The selection of exact values for these dimensions is a matter of design choice and is somewhat dictated by the selection of the line scan camera **460** used for the positioning determination. The overall target **500** has a width **W3** and a height **H2** such that the parallel oriented indicia **501**, **502** extend substantially along the full height of target **500** while the diagonal indicia **503** traverses a significant portion of the width **W3** of target **500**. The parallelogram shaped indicia **503** as illustrated in **Figure 5** does not come in contact with either indicia **501** or **502** but is spaced apart there from by a distance **D1** in order to provide three distinct indicia for positioning purposes. Optionally, indicia **503** can be joined at either end with indicia **501** and **502** to form a substantially N-shaped pattern on target **300**. The parallelogram shaped indicia **503** is angled at an angle α from the horizontal as shown in **Figure 5**.

However, in the prior art, camera vision system **360** is a line scan camera and thus, takes up a considerable amount of space either above the robotic arm **110** and cartridge retrieval mechanism **145** (also referred to as a robotic hand or gripper) or below the robotic arm **110** and cartridge retrieval mechanism **145**. This extra space needed for the camera vision system **360** reduces the number of storage cells **130** that can be placed in a given area since vertical space needed to accommodate the camera vision system **360** cannot be used to provide storage cells **130**. Therefore, in order to increase the

density of storage cells **130** in a particular library, the camera vision system **360** of the present invention is implemented as a barcode laser scanner rather than a line scan camera as was typical in the prior art. Barcode scanners are commonly available products used in systems, such as, for example, check out scanners for super markets and are well known in the art. A barcode scanner is smaller than a line scan camera. Therefore, less space is needed to accommodate the barcode scanner. Thus, more room is available for storage cells, thereby increasing the storage density of a storage library.

With reference now to **Figure 6**, a diagram of a barcode scanning apparatus suitable for use with a cartridge retrieval system is depicted in accordance with the present invention. Barcode scan apparatus **602** may be implemented as the camera vision system **360** in **Figure 3**. Barcode scan apparatus **602** includes a barcode laser or charge coupled device (CCD) scan engine **604**, and an aperture **606**. Barcode scan apparatus **602** is smaller than the line scan camera used in the prior art. Therefore, a smaller amount of space is necessary to accommodate the camera vision system **360**. Thus, more space in the library storage system may be devoted to storage cells, thereby increasing the storage density of the library storage system.

Barcode scan cameras or engines have not been used for calibration purposes in the prior art because the output from barcode scanners is merely the decoded value of the bar code scanned by the barcode scanner. Therefore, barcode scanners do not provide any pixel

data. Furthermore, the scan width of the laser scanner beam from the barcode laser scanner is not controlled. Therefore, the proper calibration measurements cannot be made. However, to overcome these shortcomings, the present invention incorporates an aperture **606** between the barcode scan engine **604** and a target barcode **608**. The aperture opening **610** must be smaller than the scan width of the barcode scan engine **604**, thus ensuring that the scan width **612** is uniform. The flexture is a mechanical apparatus within the barcode scan engine that controls the movement of the mirror that reflects the laser light across an area. Since the flexture is mechanical, the movement of the robotic arm **110** during the calibration procedure will affect the flexture causing the scan width **612** to be variable. The aperture **608** is situated to reduce the scan width generated by the movement of the flexture such that the scan width is uniform. This produces a non-variable scan-width giving a controlled end of scan.

To determine the center of the target in the direction parallel to the scan path, the robotic arm **110** is moved in the direction of scan path until the target **608** first becomes readable. This position is recorded through the use of a positional encoding device. The robotic arm **110** continues to move in the same direction until the target is no longer readable by the barcode scanner apparatus **602**. This position is also recorded. The center of the target in the scan path direction is then the half distance position between these two positions.

With reference now to **Figure 7**, a diagram illustrating a method of determining the target position center when the scanner is moving perpendicular to the barcode scan path is depicted in accordance with the present invention. Barcode scan apparatus **602** is moved in a direction perpendicular to the barcode scan path **612** by robotic arm **110** until the target **608** is first readable by the barcode scan apparatus **602**. The position is recorded through the use of a positional encoding device. The barcode scan apparatus **602** continues to move in a direction perpendicular to the scan path **612** until the target **608** is no longer readable by the barcode scan apparatus **602**. This position is also recorded. The half distance is calculated which provides the center position of the target in the direction perpendicular to the barcode scan path **612**. The target **608** may be a barcode similar to that depicted in **Figure 8**.

With reference now to **Figure 9**, a diagram depicting more detail about the aperture associated with the barcode scan apparatus is depicted in accordance with the present invention. As depicted, the aperture **606** opening is beveled to ensure that specular reflections are not sent back into the scanner **604**. Furthermore, the aperture should be black anodized (i.e., black matt with powder coating that spreads or scatters light) to further ensure that specular scattering does not result in light being reflected back into the scanner **604** from the aperture. In some embodiments, the aperture is constructed from metal. However, other materials may be utilized. The sharper the bevel, the less likelihood of

specular reflections being sent back into the scanner **604**.

The description of the present invention has been presented for purposes of illustration and description, and is not intended to be exhaustive or limited to the invention in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art. The embodiment was chosen and described in order to best explain the principles of the invention, the practical application, and to enable others of ordinary skill in the art to understand the invention for various embodiments with various modifications as are suited to the particular use contemplated.